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ENVIRONMENTAL RESEARCH

THE POTENTIAL USE OF UNDERWATER ACOUSTICS FOR CONTROL OF ZEBRA MUSSELS: FIELD STUDIES

RAC Project No. 690C
FINAL REPORT

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FINAL REPORT

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ACKNOWLEDGEMENT AND DISCLAIMER

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THE POTENTIAL USE OF UNDERWATER ACOUSTICS FOR CONTROL OF ZEBRA MUSSELS: LABORATORY AND FIELD STUDIES

1.0) INTRODUCTION

The introduction of zebra mussels (Dreissena polymorpha) into the Great Lakes and their impact to all water users on these lakes and associated tributaries has resulted in an intensive search for methods to control this unwelcome introduced species.

In structures such as water intake cribs and associated service water systems, zebra mussel infestation and colonization can result in losses in hydraulic capacity, clogging of strainers, obstruction of valves and small diameter piping including fire protection. Nuisance problems associated with decay of mussel tissue or removal of shell material and associated byssal attachment threads are also wide spread.

Chemical oxidants, particularly chlorine, have been used widely for control of zebra mussel infestations in both Canada and the United States. The combination of proven effectiveness and familiarity with its application and associated hazards has resulted in the approval of chlorine for use against zebra mussels in Ontario; under the condition that strict control requirements are followed.

Treatments utilizing chemical oxidants appear to have been very effective, however there are several reasons why the search for alternative control strategies continues.

Disadvantages of using chlorine are well documented and include the potential formation of trihalomethanes (THMs) and chlorinated organics, possible increased potential for corrosion, particularly for carbon steel piping, as well as taste and odour problems. Chlorine can also interfere with water end use such as in greenhouses, golf courses, inactivation of biological filters in industrial complexes, as well as safety concerns for handling and storage.

The move to alternate oxidants or other potentially toxic materials does not appear to be wise in that there may arise a host of new production, handling and environmental concerns which may or may not prove more potentially damaging than those already well understood with chlorine.

It is obvious then, if available, new control measures should be non- chemical in nature or at least be useful in reducing the amount of chemical (chlorine) presently used. Small scale service water systems, such as those listed above, may benefit greatly from the development of new non-chemical control technology.

As part of this ongoing "non chemical" approach to zebra mussel control it was felt that further investigation of underwater acoustics may lead to the development of another potentially useful and readily available tool for reduction or elimination of downstream zebra mussel settlement. Preliminary results from a study done by Sonalysts Inc., of Waterford, Connecticut, in conjunction with Aquatic Sciences Inc., and funded by the Empire State Electric Energy Research Corporation, suggested that exposure to acoustic energy might discourage settlement in veligers immediately downstream and may

result in extensive mortality in both adults and veligers. Further study was necessary to determine the potential for development of this technology.

The objective of the proposed study was initially to be twofold, involving significant investigation of behavioral and physical effects of various power levels and acoustic frequencies on veliger, post veliger and young adult mussels, however budget reductions caused a down-scaling of the project to short term field trials with one already established frequency. This work focused on the potential to eliminate zebra mussel veligers from the water column in a flow through test chamber and determine whether downstream settlement could be discouraged.

Of the number of sites in the immediate vicinity of our St. Catharines facility that could provide adequate conditions for the research, Ontario Hydro's Decew Falls Generating Station was chosen as the most appropriate. This site offered power and shelter, as well as a heavily infested body of water that has had significant zebra mussel settlement over the past three years and has frequently had veliger concentrations in excess of $20{,}000/m^3$.

2.0) EQUIPMENT DESIGN

Both acoustic system and flow-through exposure chamber studies were completed during the month of September.

The acoustic system consists of a central control unit that can power remote transducers positioned to take advantage of the best radiation pattern.

The system is comprised of integrated circuits capable of producing a high accuracy sine waveform. The frequency is internally set at 43 Khz. The circuit ensures stable frequencies over a wide range of temperatures by using phase locked loop technology, frequency drift is less than 250 ppm/C. The specifications are as follows:

GENERATOR

Input Power:	110-120 VAC - 60 hz
Output Power:	1,800 Watts - 600 Watts/channel
Output Frequency:	46 Khz plus complex resonances (50-90 Khz)

IMMERSIBLE TRANSDUCER

Piezoelectric Elements:	PZT lead zirconate titanate
Curie Temperatures:	570°F heat stabilized at 400°C
Transducer Housing:	304 stainless steel mirror finish
Size:	23 x 6 x 3½ inches/58.4 x 15.2 x 8.9 cm

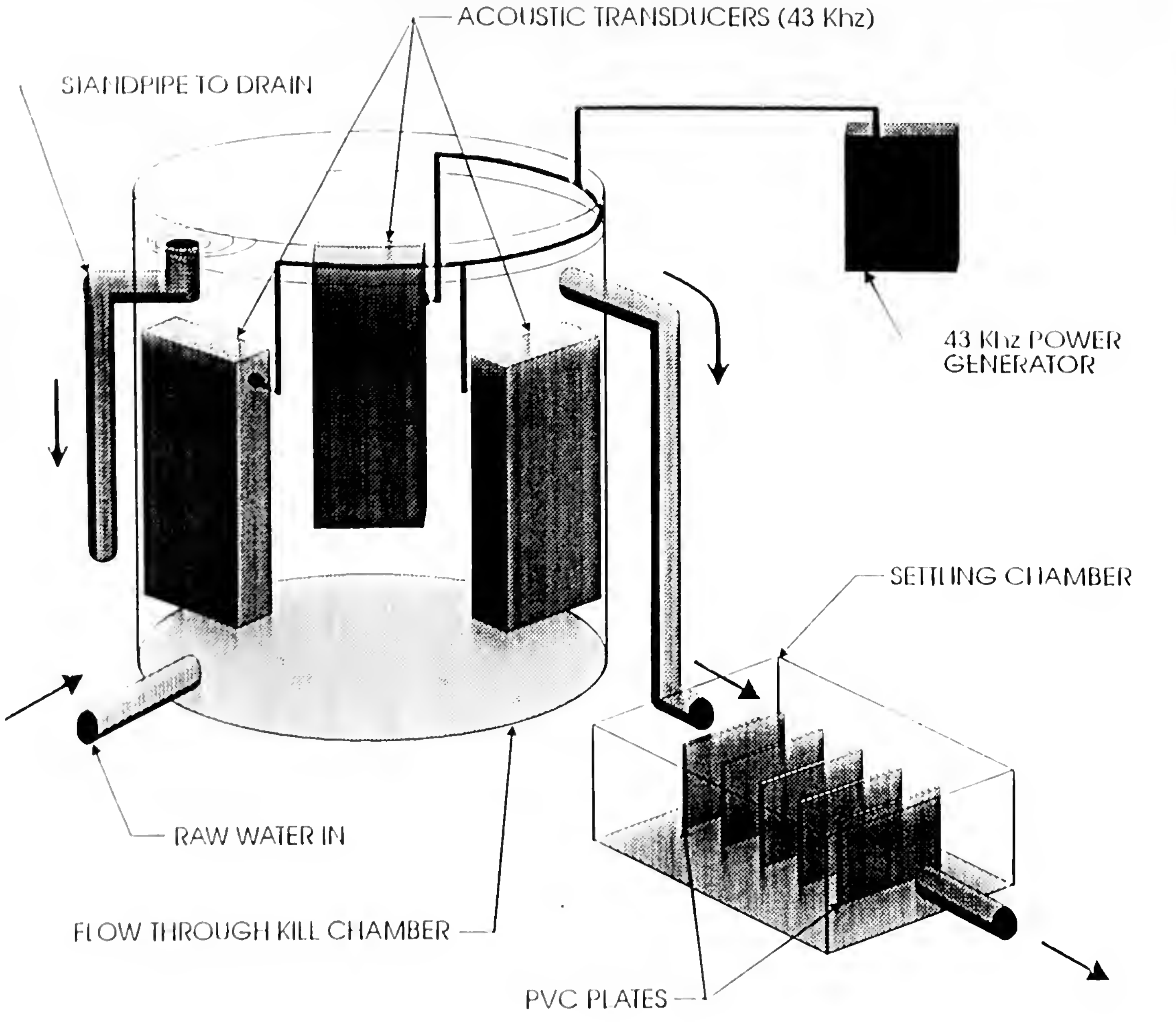
Inside the transducer PZT elements are bonded to the radiating face. These transducers incorporate PZT ceramic discs sandwiched together for greater operating strength and longevity. The radiation pattern is designed for 120° coverage.

3.0) FIELD TRIALS

Due to reduced budget the study was designed to determine the feasibility of using the proposed system for removal of veligers and post veligers in flow through applications only. Preliminary laboratory trials on veliger larvae were not completed nor were trials on adult mussels.

As mentioned, acoustic transducers with an output frequency of 43 Khz were chosen based on results of previous research. This frequency has been the most effective to control mussel larvae in previous work completed by Sonalysts Inc. and Aquatic Sciences Inc. for the Empire State Electric Energy Research Corporation (ESEERCO).

A flow through kill zone was fabricated in which three acoustic transducers were located. (Figure 1). Veliger laden water was pumped through this chamber from the raw water source. All water was forced to pass through this "kill zone" and within the zone of influence of the transducers at a rate of approximately 15 L/min.



Aquatic Sciences Inc.

ACOUSTIC CONTROL OF ZEBRA MUSSELS

PROJECT NUMBER AN172

SUPERVISOR D. LEWIS	
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FIGURE 1

In addition to 20 L water samples which were collected and analyzed for mussel larvae or juveniles, both upstream and downstream of the kill chamber, PVC plates were put in a downstream settling chamber in order to determine the effectiveness for prevention of downstream settlement.

Daily sampling included microscopic analysis (80 x magnification) of concentrated 20 L water samples. Age and survival of larval and juvenile mussels were recorded. General condition of larvae was also noted.

In addition, accumulated biofilm on settling plates was scraped into 500 ml plastic jars and samples were analyzed under 40 x and 80 x magnification to determine whether downstream settlement had occurred. Biofilm was also cleaned from downstream settling chamber walls and analyzed for settled mussels.

Age, density and type of settled mussels were to be determined should they be found in the settling chamber or on other surfaces.

It has been previously noted in research completed by Aquatic Sciences Inc. that during treatment with oxidants or ultraviolet light mussels often become inactivated but not killed following exposure to a treatment zone or kill chamber. When this happens, swimming activity ceases for a period of time and mussels may pass through a system or fall out of the water column in a deposition zone. This has been observed by ASI technicians during analysis of settling patterns and behavioral studies for a number of other control technologies.

In order to determine whether mussels were inactivated by the system and passing further downstream to settle, the overflow standpipe from the kill chamber was cut into 15 cm sections and split in half. Biofilm from three of these sections, 1, 3 and 5 meters downstream from the chamber was also analyzed for mussel settlement.

In addition, the contact chamber walls were visually examined for live juvenile mussels at the end of the study.

This project was completed between October 1 and November 30, 1994 (2 months). Due to this relatively late start, and the increasing cold water temperatures as time progressed, larval numbers were low. The study was therefore continued as long as mussel larvae were detected in the water column to provide the maximum number of test organisms.

4.0) RESULTS/DISCUSSION

When reviewing the results of the present study, it should be remembered that very low veliger densities were often recorded in any one sample and therefore percent mortalities can be misleading. Regardless, the total number of test organisms was significant when taken in the context of the entire study period. Total numbers of incoming veligers and post veligers, as well as mortalities upstream and downstream of treatment are found in Figures 2 to 4 and Appendix 1.

FIGURE 2: ACOUSTICS RESEARCH - DECEW HYDRO HEADWORKS

UPSTREAM MONITORING RESULTS

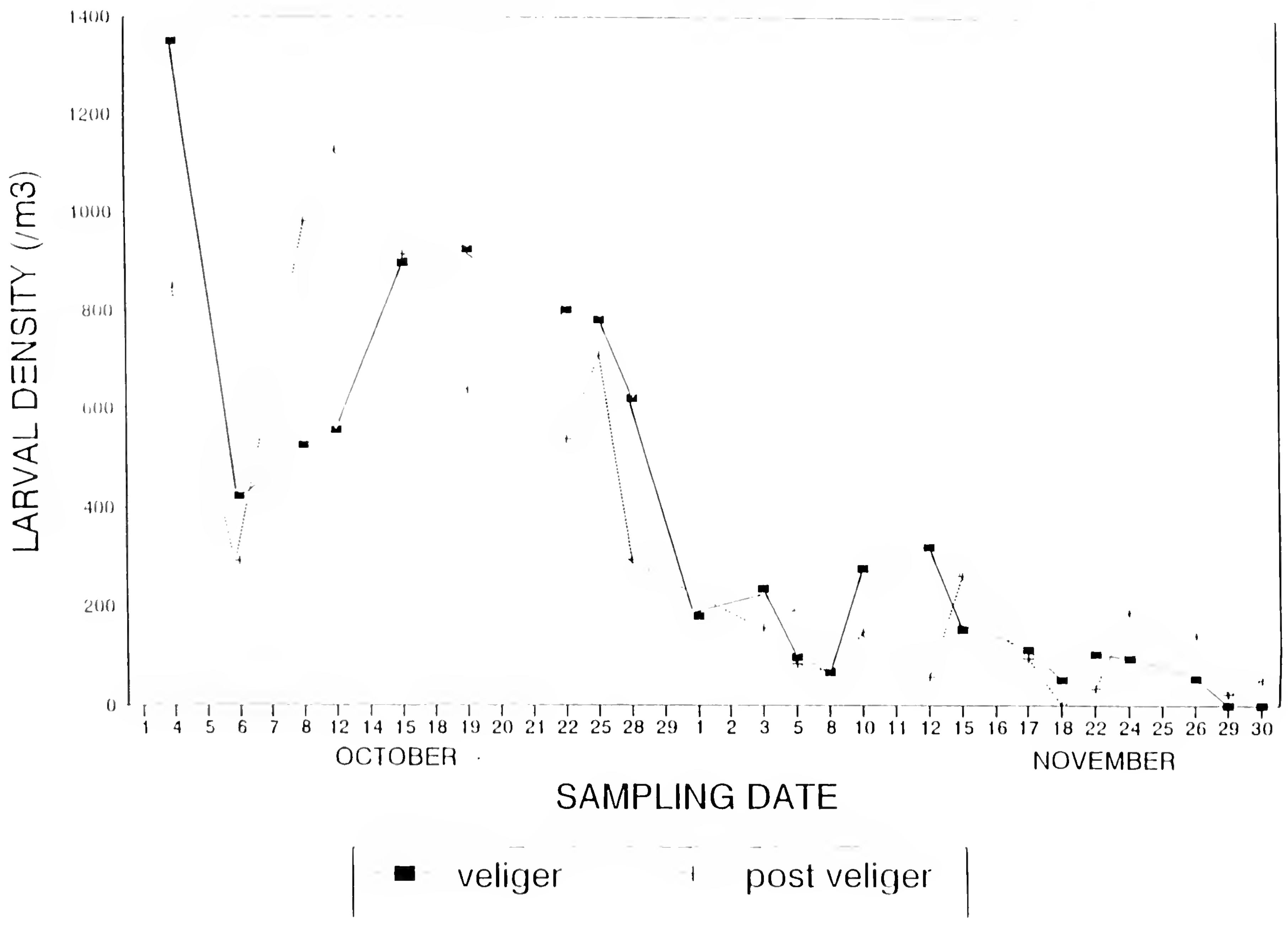

FIGURE 3: ACOUSTICS RESEARCH - DECEW HYDRO HEADWORKS
VELIGER MORTALITY

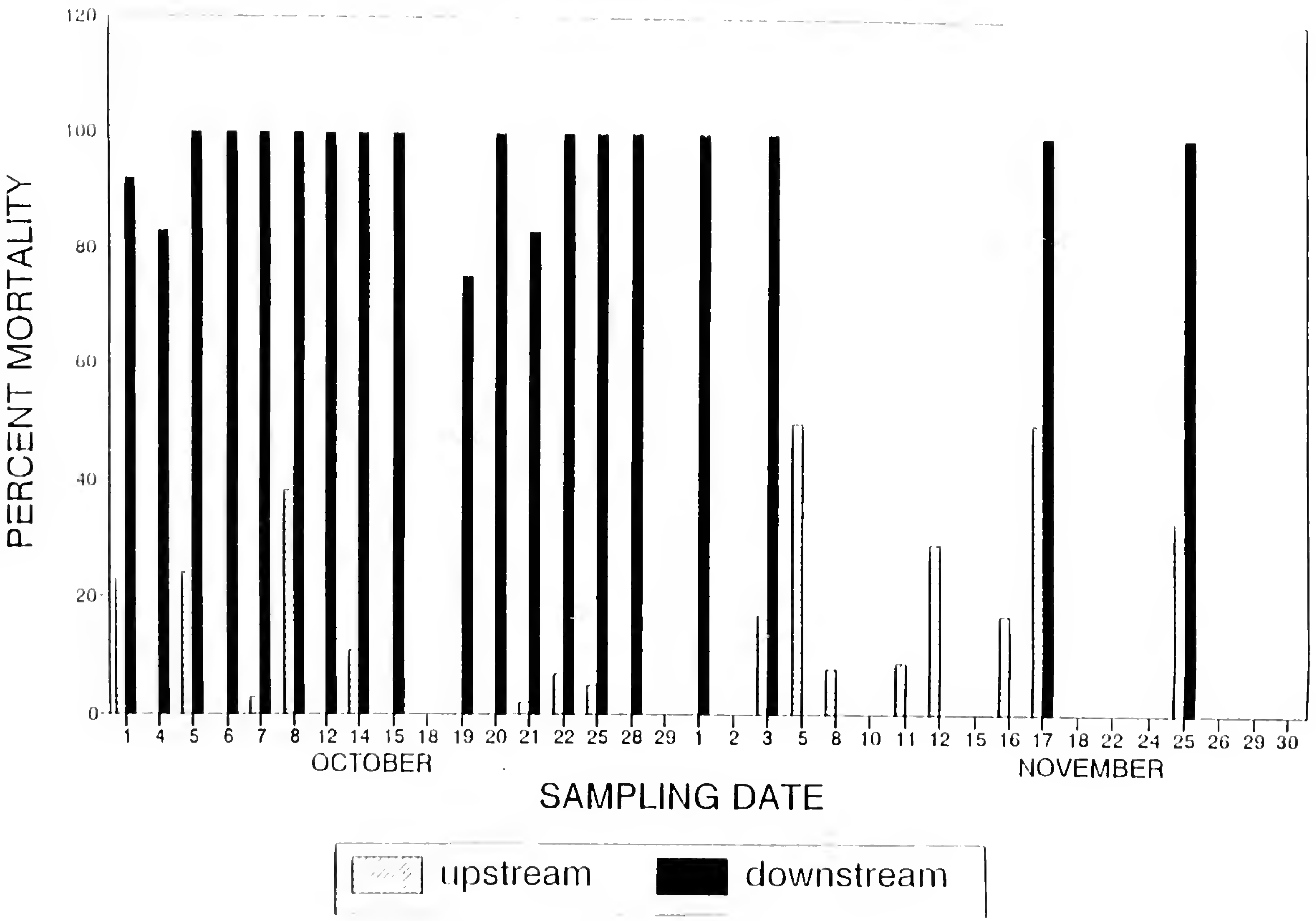

FIGURE 4: ACOUSTICS RESEARCH - DECEW HYDRO HEADWORKS

POST VELIGER MORTALITY

Controlling post veligers is generally of more concern to industrial complexes due to their potential for settlement within the relatively short time they will spend within these complexes. Detention times for cooling water vary from as low as 5-10 minutes to 30 or 40 minutes. Veligers for the most part will pass through cooling water systems without causing problems.

In general, this technology appears to have been relatively successful in terms of causing short term mortalities to both veliger and post veliger larvae. Mortalities in downstream samples were 100% for veligers and post veligers except for a few occasions when mortalities as low as 50% were observed for post veligers and 75% for veligers. The mortalities in the pre-treatment or upstream samples ranged from 0 to 50% for both veligers and post veligers.

Mussel larvae were observed to be in poor condition after passing through the kill zone. Shell material was often shattered and tissue extruded from the shell. These results are similar to those reported in the Sonolysts' work at comparable frequencies.

It is not known why on a few occasions mortalities were less than 100%, however it has been speculated that these individuals may have passed through the system associated with debris. It is also possible that power may have been inadvertently turned off at this system. Maintenance crews were working in the vicinity of this study during the fall and power outages were occasionally experienced. Again the low number of individuals in samples are also likely contributing to these potentially misleading percent mortalities which may be over-emphasizing the importance of an individual live animal.

The results from the analysis of the downstream settling plates, shown in Table 1.0, indicate that no downstream settlement of juveniles occurred. These results further indicate that this technology is potentially capable of preventing downstream settlement. Samples from the settling plates were taken at the end of the test period. It should be noted that relatively few post veligers were noted through this test period and that very little settlement was noted on upstream substrates. In many cases, no settlement was observed upstream and was always less than $100m^2$.

The trial system was an electronic acoustical device that generates ultrasonic waves of energy. This energy has the property of disorienting perceptual and motor skills along with upsetting the normal metabolism of most fauna. What this means is, after exposure to this energy, fauna may lose their appetite, lose the urge to mate, change eating habits, and become aggressive and disoriented to the existing environment. These effects often occur within a short time period in more complex organisms. There may be some other similar but undefined behavioral effects no larval mussels.

Obviously many aspects will affect the performance of this device in the amount of energy required, in the effective range, and the time required. The pressure phase of the sound wave is directed at the mussels and becomes a point of negative pressure. In the zone of liquid where a negative pressure exists, the water begins to vaporize and form tiny bubbles (cavitation). In one half of a cycle, 1/80,000 of a second (at 40 Khz), the pressure returns positive and the bubbles burst. This is cavitation and should not be confused with degassing. Each bubble that implodes has a calculated pressure of about 10,000 psi. In theory this could generate temperatures in excess of 20,000 °F. The actual pressure and temperature

TABLE 1.0:
ULTRASONIC ACOUSTIC BREAKDOWN ANALYSIS

Downstream Plate and Wall Scrapes

Sample Type	Juvenile Density (/m2)	Juvenile Mortality (%)
Outflow Wall Scrape	0	
Inflow Wall Scrape	0	
Right Wall Scrape	0	
Left Wall Scrape	0	
Plate #3 Scrape	0	
Plate #4 Scrape	0	
Overflow Tube Scrap	0	
Overflow Tube Scrap	0	
Overflow Tube Scrap	0	

is lower due to viscous effects of water. These physical parameters are difficult to measure on a microscopic scale and the exact physical affects in this study are unknown. It is this action, we believe, that causes the damage and mortality in the mussels whether physical or physiological.

Previous work by Sonolysts and ASI showed favourable results, reducing zebra mussel infestation (Sonolysts, Aquatic Sciences Inc., 1991). It was reported that this system is effective through the range of 20-42 Khz at 170-270 db, with the most effective being a 40 Khz sweep at 194-197 db. The juvenile kill rates were 100% within one minute of exposure to these parameters and 100% mortality, regardless of size, within five minutes. Veligers had a mortality of 90+% within 15 seconds.

These results appeared to reduce downstream settlement of mussels under low flow conditions. The results of the present study appears to confirm those observations, however, the lower numbers of test organisms leaves these results in question.

Follow up work is recommended to further test this equipment under more rigorous conditions of heavy mussel infestation. In addition, flow rates were relatively low during this trial. Maximum effective flow rates need to be established in order that the full potential of this technology for a variety of applications is defined. It will also be important to determine whether immediate mortality is necessary to control infestation or whether a significant latent effect could result in behavioral changes inhibiting settlement or ultimately causing mortality.

The cleaning capabilities of this technology have not been pursued in terms of the possibility of removing mussel infestation from underwater structures. The ability of transducers emitting the 40 Khz frequency to shatter mussel shells raises the question of whether they can be used to clean surfaces of established mussel colonies at close range.

5.0) CONCLUSIONS

The following conclusions can be made from this study:

i) The study was conducted very late in the breeding season. This resulted in relatively low numbers of specimens per sample that in turn, increased the potential for error in the final mussel percent mortality determination that is directly attributed to the acoustic equipment.

ii) There were very high mortality rates recorded downstream of the acoustic transducers in the kill zone when compared with the upstream natural mortality rates and mortality in controls of other studies at the same site. Downstream mortality rates ranged form 70 to 100% for veligers and from 50 to 100% for post veligers. Most samples exhibited 100% mortalities for all life stages observed.

iii) No juvenile mussels were observed on the settlement plates located downstream of the kill zone. This indicates that the acoustic technology option has potential for prevention of downstream settlement, although poor settlement in untreated substrate again temper this conclusion. While there was no true control or duplicate untreated system it was generally observed that little larval settlement occurred at this site over the study period.

iv) Further study is required to confirm that these results are reproducible in an industrial, municipal, commercial and/or residential environment. To date only very low flows have been tested. This technology must be more rigorously tested on a small scale before larger studies are attempted.

v) Surface testing may be an important additional area to further define the capabilities of acoustic control technologies and may have implications with regard to their application in the field of underwater robotics technologies for intake & pipe cleaning.

Overall, the results indicate the use of acoustics for the control of zebra mussels has significant potential for success and should be pursued from both a flow through and surface cleaning potential. The non-chemical nature of this device makes it an ideal long term control technology should it prove effective for a number of different flow regimes.

APPENDIX 1

APPENDIX 1:
ULTRASONIC ACOUSTICS STUDY AT THE DECEW TEST SITE

Collected Data

Location:	Test Tank				Dock Plankton Haul			
Date	Veliger Density (/m3)	Veliger Mortality (%)	Post Veliger Density (/m3)	Post veliger Mortality (%)	Veliger Density (/m3)	Veliger Mortality (%)	Post Veliger Density (/m3)	Post veliger Mortality (%)
Oct 1	1140	92	285	67				
Oct 4	720	83	240	100	1349	23	853	16
Oct 5	80	100	0					
Oct 6	575	100	230	100	422	24	291	5
Oct 7	520	100	1170	100				
Oct 8	170	100	595	100	527	3	984	5
Oct 12	700	100	175	100	556	38	1129	30
Oct 14	440	100	110	100				
Oct 15	550	100	110	100	900	11	916	12
Oct 18	0		0					
Oct 19	420	75	210	50	927	0	639	6
Oct 20	840	100	140	100				
Oct 21	660	83	330	100				
Oct 22	270	100	135	100	802	2	540	0
Oct 25	130	100	0		782	7	709	13
Oct 28	175	100	175	100	622	5	295	6
Oct 29	0		175	100				
Nov 1	150	100	150	100	180	0	180	11
Nov 2	0		0					
Nov 3	250	100	0		235	0	156	0
Nov 5	0		350	100	98	17	82	20
Nov 8	0		0		65	50	65	50
Nov 10	0		0		276	8	148	0
Nov 11	0		175	100				
Nov 12	0		0		320	9	58	0
Nov 15	0		0		153	29	262	17
Nov 16	0		160	100				
Nov 17	490	100	0		113	17	94	0
Nov 18	0		105	100	51	50	0	
Nov 22	0		0		104	0	35	0
Nov 24	0		0		95	0	189	0
Nov 25	375	100	375	100				
Nov 26	0		155	100	53	33	141	12
Nov 29	0		0		0		23	0
Nov 30	0		0		0		51	0

REFERENCES

1. Sonolysts, Inc. and Aquatic Sciences Inc., 1991, Zebra Mussel Deterrence Using Acoustic Energy, Research Report Ep. 90-38. Empire State Electric Research Corporation (ESSERCO), 1991.